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# AERIAL MISSION FOR THE STUDY OF THE AURORA AND OF THE SKY AT NIGHT IN THE REGION OF HIGH LATITUDES



D. Barbier, M. Fafiotte, and G. Weill



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NOTES

# AERIAL MISSION FOR THE STUDY OF THE AURORA AND OF THE SKY AT NIGHT IN THE REGION OF HIGH LATITUDES,

Daniel Barbier, Marc Fafiotte, and Gilbert Weill.



Summary: An aerial mission was carried out from 4 to 11 December in the auroral region, during a period of magnetic calm.

The auroral arc is emitted at a slightly greater altitude for the radiation 6,300 than for 5,577.

The relation of the intensities measured at the same distance from the zenith for these two radiations is a function of the distance of the arc from the observer. The geographic position of the arc is connected with the magnetic activity. The intensity of the nightly luminescence for the two radiations under consideration has remained weak, and its study was hampered by the aurora, and at the lower latitudes by clouds. author

## INTRODUCTION

The emission of the red line of the sky at night, for the low and medium latitudes, is now sufficiently well known, on the basis of the measurements performed from the ground by various teams of observers, and on the basis of the measurements obtained over Africa in airplanes, on two successive occasions.

Above latitude 45° North, we know only the Soviet measurements that were performed, in connection with the Geophysical year, at Zvenigorod ($\varphi = 55°43'$) and at Loparskaya ($\varphi = 68°15'$). At the first one of these stations, the behaviour of 6,300 Å is still largely analogous to the one observed by the stations of medium latitude. At Loparskaya, the observations, which - incidentally - were not very numerous, show a rather erratic behavior that is due to the fluctuations of the aurora which superimpose themselves over the normal emission of the sky at night.

An aerial mission was organized for the time from 4 to 11 December, for the purpose of studying in the most homogeneous manner possible, the connection between the red lines of 6,300 Å and the green lines of 5,577 Å of the sky at night, in the proper meaning of the words, and the intensities of the auroral zone. A preliminary mission that had been carried out, in the same regions, from 30 October to 3 November, was already the subject of an earlier publication /I/.

The itinerary of the mission of December was the following: night from 4 to 5 December: Creil (France) - Helsinki, Stockholm. Night from 6 to 7 December: Stockholm - Keflavik (Iceland). Night from 8 to 9 December: Keflavik - Helsinki. Night from 10 - 11 December: Helsinki - Creil.

The flight of the night from 4 to 5 December was not favored inasmuch as the weather was concerned, which made only very few observations possible, and those only while the airplane was at a latitude of more than 57°. The other flights were carried out under good conditions, with the exception of the last flight, which did not enable us to make any observations at latitudes below 55°5. In general, the altitude of the plane amounted to 8,500 meters.

The mission included, besides the signers of this paper, the crew of the B-17 airplane of the National Geographic Institute: Messrs. Fournier (pilot), Derne (navigator), Romensky (radio), and Izard (mechanic).

The photometer used was the rotary photometer; it explored the sky at 15° below the horizon and had been used during other aerial missions. It was equipped with two filters focused on 6,300 Å and with two filters focused on 5,777 Å. For each one of these combinations, one of the filters was narrow and the other one wide in such a way that, in accordance with a method that is usual in our observations, it was possible to eliminate the continuous spectrum (extra-terrestrial and atmospheric) from our measurements.

During the entire period from 4 to 11 December, the magnetic activity remained weak; $K_p$ did never exceed the value of 4+; in the night from 2 to 3 December, i.e., two days before the beginning of our operations, $K_p$ had reached a value of 7-.

## RESULTS IN REGARD TO THE POLAR AURORA

As we have already stated, all observations were carried out at latitudes of more than 55°5. On our recordings, within a radiation of 5,577 Å as well as within the radiation of 6,300 Å, the aurora was always visible toward the North, except at the end of the flight of 8 December from Keflavik to Helsinki. During this flight, the aurora became dubious at 0:39 hours A.M. standard local time, and during the last cycle observed (2 hours, 38 min. for 6,300 Å and 2 hours, 55 min. for 5.577 Å), it was almost certainly, lacking.

Most frequently, the aurora produced one maximum only on the record; it was located toward the North, i.e., in the usual terminology, a diffuse glimmer (glow) was present. In reality, this aurora which was recorded as a glow, visually appeared, quite often, to the member of our team who took care of the visual observations, as a true homogeneous arc that was located at a very much lower altitude above the horizon than the altitude of the small circle scanned by the photometer (15°). On the flight of 6 December, in particular, the visual observer found the presence of an arc located at an altitude of 5°, during the larger part of the flight, and only when this arc rose up and attained an altitude close to 15°, it appeared finally on the recording in the form of a double maximum, first in the radiation 6,300, and then in the radiation 5,577 (Fig. 1). This separate appearance of the red arc and of the green arc in the recording shows that the red one is located at an altitude that is slightly higher than the altitude of the green arc. This effect had not been observed during the flights of the previous mission, since either the airplane had been in the neighborhood of the arc so that its components - the red one and the green one - were projected, to the

observers, one above the other, or the airplane moved more or less vertically to the direction of the arc so that the rotation of the photometer was too slow (6 minutes for the recording of one radiation around the horizon) and the effect passed unnoticed. On the other hand, the flight of 6 to 7 December, the route of which formed a small angle with the direction of the arc, made it possible to show clearly this difference of the altitudes of the components 5,577 and 6,300 of the arc.

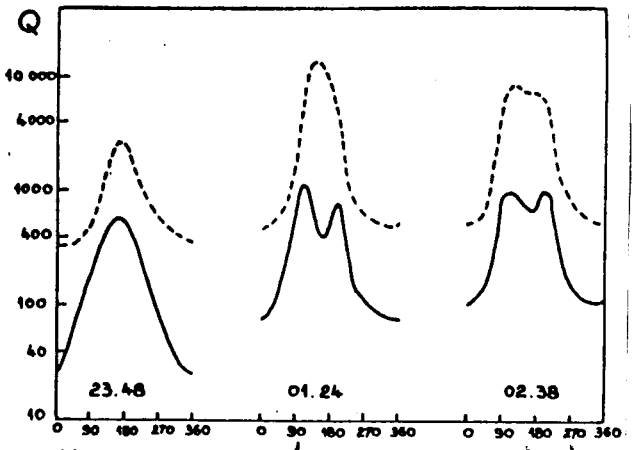


Fig. 1. Intensity around the horizon, at a distance from the zenith of 75°, of the line of 6,300 Å (solid line) and of the line of 5,577 Å (dotted line), when the observer approaches the auroral arc slowly. This arc appears at 1:24 hours for the first line, and at 2:38 hours for the second line (6 December 1961).

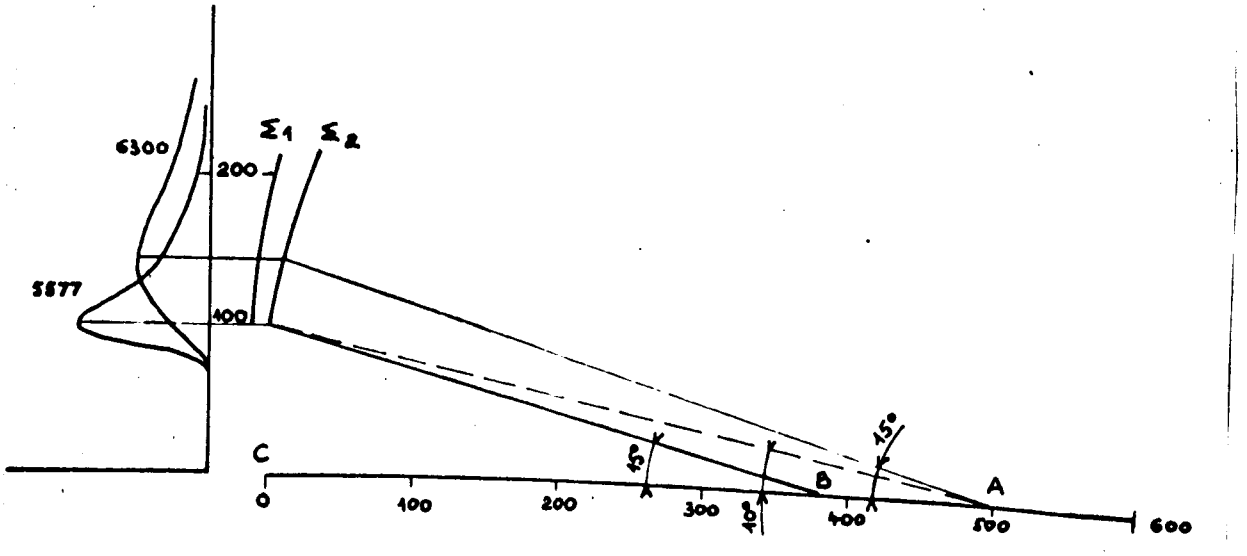


Fig. 2. The arc 6,300 attains 15° at A, and the arc 5,577 then culminates at 10° only. It follows therefrom that the arc of 6,300 Å is being emitted at an altitude that exceeds by some 40 km the emission altitude of the arc 5,577.

The schematic drawing of Fig. 2 shows the details of the interpretation of this phenomenon. It is assumed that the arc of the aurora is excited by particles that find themselves comprised between two surfaces, $\Sigma_1$ and $\Sigma_2$, that correspond to two values near the parameter of McIlwain's layer L. The emission within the arc, per unit of elevation, for 5,577 and 6,300 has been shown as a function of the altitude, on the left part of the figure; the corresponding curves have not been actually observed, but they agree with a possibility that takes into account the very considerable de-energising that takes place at the low altitudes of the level $^1D$ of the oxygen atom. When the airplane is at A, the arc is in the field of the photometer, i.e., at a height of $15^\circ$, within the radiation of 6,300 Å, but the observer who operates visually, i.e., essentially within the radiation 5,577, estimates its height at $10^\circ$. When the airplane is at B, then the arc in the radiation 5,577 will become distinct on the photmetric recording, and the visual observer will also note that its altitude amounts to $15^\circ$. Figure 1 shows that the altitude of the red arc is still 40 km higher, when we estimate the altitude of the green line to be 100 km above the airplane. This figure is certainly not exact, since it is the result of rough estimates of the angular heights of the green arc. When the airplane is located at C, near the arc, then the red and green arcs will be projected practically one atop the other.

In accordance with the preceding remarks, the red arc and the green arc are, therefore, two different aspects of just one phenomenon, even though they may be located at slightly different altitudes.

In the preceding Note, it has been demonstrated that the ratio of the intensities of the green and red lines Q(5577)/Q(6300), which is of the order of 10 when a homogeneous auroral arc is observed from very close by, will decrease to values of the order of 3 at a time, when it is still being observed farther away from the arc, at $15^\circ$ above the horizon. The pertinent Fig. 3 had been prepared

with the aid of roughly estimated distances from the arc. Fig. 3 of this paper has been plotted on the basis of the distances that are the result of the visual estimates of the height of the arc above the horizon. It is, certainly, even less exact but it seems to us that it opens up an interesting possibility that would enable us, on the basis of photometric observations that would be made at a fixed distance from the zenith, and that would, therefore, be reasonably precise, to determine the position of a homogeneous isolated auroral arc. The properties of the aurora during the periods of magnetic inactivity are practically unknown, and the study of its movement above the terrestrial globe could be advanced on the basis of those observations.

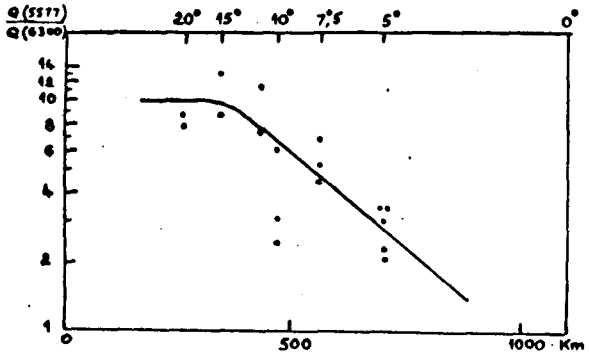


Fig. 3. Ratio of the intensities of the lines of 6,300 Å and of 5,577 Å, as a function of the distance of the observer from the arc.

In order to pursue here, as much as possible, the investigation of these possibilities, we have prepared (Fig. 4) maps of the positions of the auroral arc for the three flights of 6 to 7, 8 to 9, and 10 to 11 December. The positions which are the result of photometric observations, in the radiation 5,777 of the arc (two maxima on the recordings) have been represented by rather long segments of straight lines, and the positions that are the result of the measurement of the ratio Q(5777)/Q(6300) have been indicated in the direction of the maximum intensity, at the distance inferred from the Fig. 3, in the form of shorter segments. Besides each observation, we have entered the hour (TU) at which it was made. In addition, we have plotted on the maps the curves having

the same values of L (for an altitude of 100 km) and which were calculated for us by F. E. Roach, to whom we are greatly indebted for this work.

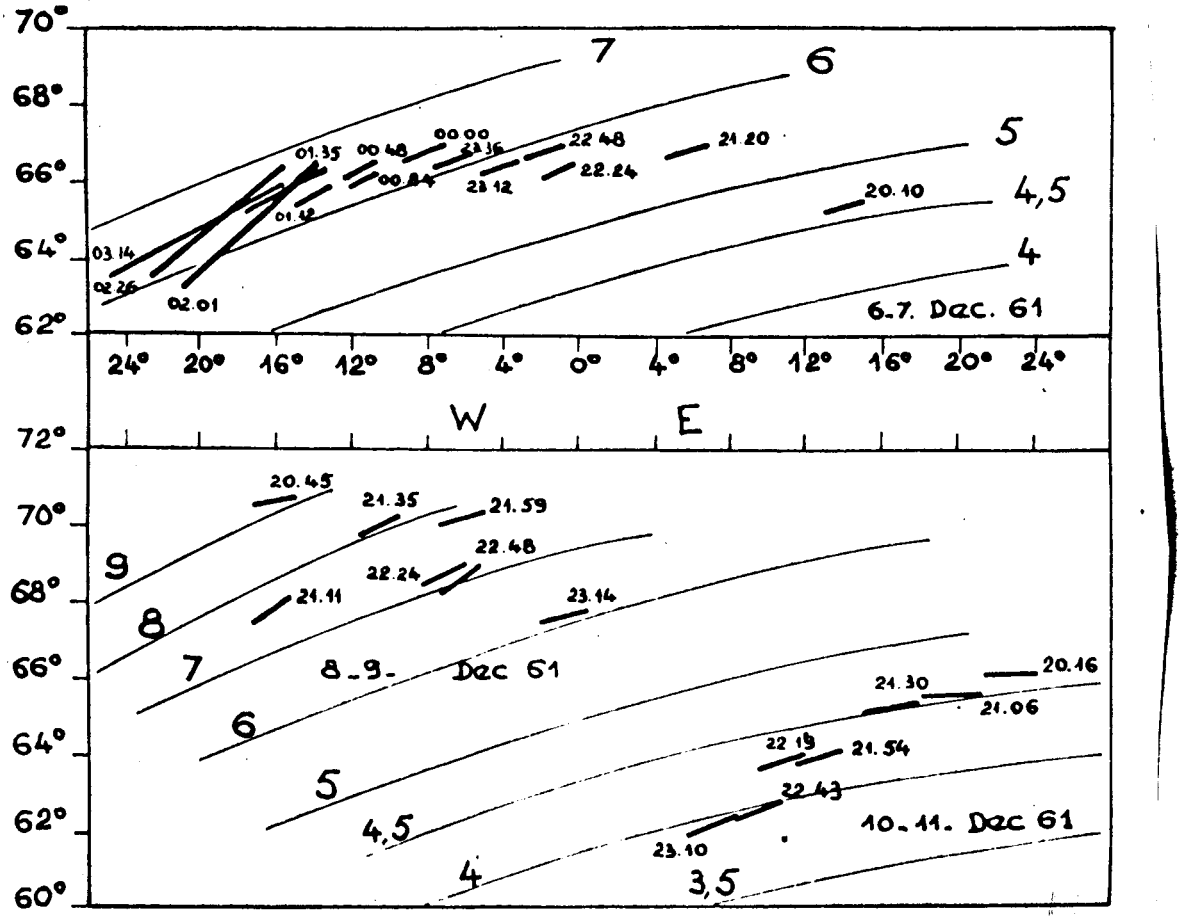


Fig. 4. Positions of the auroral arcs as observed.

The value of L is correlated to the value of $K_p$. We shall have the following for the nights of our observations in December, to which we have added the night of 30 October (1):

| Date 1961 | 8 déc. | 30 oct. | 6 déc. | 10 déc. |
|---|---|---|---|---|
| $K_p$ | 0° | 1+ | 2° | 2+ |
| L | 7,6 | 7,4 | 6,1 | 4,3 |

The intensity of the aurora appears to be in a much less close correlation with $K_p$. As a matter of fact, the night of 30 October is the one of the four nights under consideration, that has presented the by far most brilliant aurora.

## RESULTS IN REGARD TO THE LUMINESCENCE AT NIGHT

The clouds have made it impossible for us to obtain measurements for the geographic latitudes of the airplane that were below $55^{\circ}5$, and this kept us from linking up in a satisfactory manner, this series of observations with the observations made on the ground at the Observatory of Haute-Provence.

As we have stated, almost all the observations show the aurora. It was only at the end of the flight of 8 to 9 December, that the aurora was, almost certainly, absent and, in any case, very weak. Fig. 5 shows the horizon measurements as observed within the radiations of 5,577 and 6,300 Å, when the latitude of the airplane was $60^{\circ}$ and its longitude was $21^{\circ}$E. These curves could also quite easily have been observed at the Observatory of Haute-Provence.

The only means to obtain information on the luminescence at night, in the real meaning of the word, is the utilization of the measurements taken in the sky in the direction that is contrary to that of the aurora, i.e., toward the South. And we shall still have to note that, during the flight of 6 to 7 December when the auroral arc attained a height of the order of $15^{\circ}$ above the horizon, the intensity toward the South increased, for the two radiations under observation, by a very considerable amount; this will have to be attributed either to the extension of the auroral arc over the entire sky, or possibly to the diffusion of the light of the arc within the lower atmosphere.

During the flight of 8 to 9 December, at the departure from Keflavik at 18:05 and 18:35 hours local time, the intensity of the radiation of 6,300 Å toward the South, was clearly larger than for all the other measurements; it attained 100 Rayleighs. It is probable that in this case we had to do with the Western "sheet" (nappe) due to the dissociative recombination of $O_2^+$.

All the other measurements taken toward the South for 6,300 Å were below 50 Rayleighs, and they were between 200 and 600 Rayleighs for the green line.

This aerial mission could be carried out thanks to the support given by Mr. J. Coulomb, Director General of the National Center for Scientific Research, and by the General Guerin, President of the Committee for Scientific Action of the National Defence. We are eager to express our appreciation to them.

We also thank the members of the crew of the airplane as well as Mme. J. Glaume who has ascertained the analysis of the observations.

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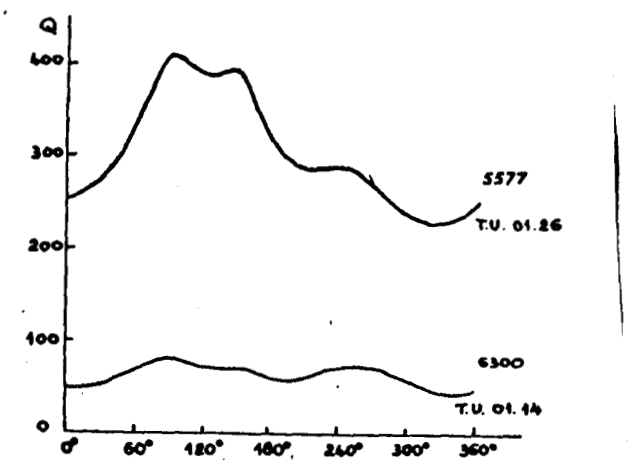


Fig. 5. Intensity of the lines 5,577 and 6,300 around the horizon, at a distance from the zenity of 75°, in the absence of the aurora. Night from 8 to 9 December, near Helsinki.